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Riparian Habitat Management for Mammals on Corps of Engineers Projects

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PURPOSE: This technical note is a product of the Ecosystem Management and Restoration Research Program (EMRRP) work unit titled "Improved Methods for Ecosystem-based Habitat Management at Corps Projects." The objective of the project is to provide appropriate technology on managing wildlife species and their habitats using ecosystem-based strategies. The emphasis is on methods that improve natural resources for a variety of animals rather than single species. This note provides an overview of the importance of riparian ecosystems to mammals, discusses regional variation in mammal communities characteristic of riparian zones, identifies potential impacts of riparian disturbance to mammals, and outlines techniques for restoring and managing riparian habitats for various species.

INTRODUCTION: Mammals are an important component of riparian ecosystems throughout the United States, but their occurrence in and dependence on riparian habitats is highly variable. Many mammals use riparian areas for food, water, and cover, especially in the arid and semi-arid western states, but few species are restricted entirely to riparian zones. Several species of large mammals range over vast areas, including upland and riparian ecosystems, but often depend on riparian areas for movement corridors and seasonal cover (Figure 1). Many small- and medium-sized mammals occur in riparian areas, but there is considerable regional variation in use patterns. Western species are attracted to the shade and moisture provided by riparian vegetation, and eastern species especially use riparian areas where surrounding landscapes have been modified by agriculture, logging, and other land uses.

Figure 1. Moose (*Alces alces*) make heavy use of riparian habitats in northern regions

HABITAT FEATURES: Riparian habitat features important to mammals include woody and herbaceous strata, diversity of food and cover plants, structural diversity (stumps, snags, fallen logs, vines), friable soil, leaf litter, available surface water, invertebrates and other prey items, and thermal cover. Instream flows and water quality are also important for aquatic and semi-aquatic species that feed on plant and animal matter in or along the stream (Ohmart and Anderson 1986). Many mammal species use a broad range of forest and non-forest habitat types, and differences in distribution within riparian ecosystems may be subtle (DeGraaf and Yamasaki 2000). Microhabitats, especially in regard to food and cover, may be the primary factors in small mammal distribution in riparian areas (DeGraaf et al. 1992).

Characteristics of riparian areas important to large mammals in the Pacific Northwest include: terrestrial forage production; aquatic foods (plant and animal); animal prey production; hiding and thermal cover; terrestrial and aquatic carrion; aquatic habitat; and burrow or denning sites (Raedeke, Taber, and Paige 1988). When compared with adjacent upland communities, riparian habitats generally had higher production of preferred food per unit area due to the following factors: (a) available free water, (b) deep, alluvial soils that produce more plant growth of higher quality than soils of adjacent uplands, (c) presence of several forest successional stages due to frequent alluvial disturbances, (d) high biotic diversity that results in enhanced range of forage, (e) diverse and abundant prey base for predators, and (f) abundance of carrion of both aquatic and terrestrial origin, providing food for scavengers.

DeGraaf and Yamasaki (2000) noted that cavity trees, dead and downed woody debris, wetland edges, young and mature hardwood stands, and coniferous habitats were needed by mammals inhabiting riparian areas in eastern forests. In the Southeast, riparian zones are especially important to mammals along streams that bisect young or regenerating forest stands (Dickson and Williamson 1988). These areas provide habitat diversity and edge for a variety of species. Features important to mammals in bottomland hardwood forests include hard and soft mast, browse, invertebrates, ground-level vegetation, tree cavities, vertical structure, and downed woody debris (Forsythe and Roelle 1990, Wigley and Roberts 1994) (Figure 2).

Figure 2. Structural diversity is important to mammals in riparian ecosystems

MAMMALIAN COMMUNITIES: Mammals can have a significant effect on the condition and quality of riparian habitats, but their importance varies regionally. Small mammals (primarily rodents and insectivores) provide an important prey base for larger vertebrates in riparian areas, especially in the West. Large herbivores such as white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*) influence forest composition through browsing on woody vegetation. Beaver (*Castor canadensis*) are especially significant in riparian areas

due to their feeding and dam-building activities. Some wildlife species inhabiting riparian areas can utilize multiple habitat types because of their mobility and adaptability. Mammals such as raccoons (*Procyon lotor*), bobcats (*Felis rufus*), gray foxes (*Urocyon cinereoargenteus*), and white-tailed deer occur in both upland and lowland areas and will move into floodplain zones when these areas are not inundated. Arboreal species, such as eastern gray squirrels (*Sciurus carolinensis*), can range vertically in riparian communities.

There is considerable regional variation in mammalian communities representative of riparian systems. Raedeke, Taber, and Paige (1988) listed 25 species of large and medium-sized mammals that use Pacific Northwest riparian forests; the larger streams and rivers at middle and lower elevations supported a greater variety of large mammals than did the streams at higher elevations. Cross (1988) listed 38 species of small mammals in riparian forests of Washington, Oregon, and northern California. Williams and Kilburn (1984) reported that approximately 25 percent (133 taxa) of California land mammals were limited to or largely dependent on riparian and other wetland communities; 21 species were said to require riparian habitats. Trapp, Linck, and Whisler (1984) reported 55 species in riparian communities of California's Central Valley. Mammals are especially dependent on riparian zones in the arid Southwest. For example, approximately 70 species potentially occur along the Rio Grande in New Mexico (unpublished data, New Mexico Museum of Natural History, Albuquerque). DeGraaf and Yamasaki (2000) listed 26 species of mammals with a strong preference for riparian habitats in the eastern United States.

CHARACTERISTIC SPECIES

Large Mammals. A variety of large mammals depend upon riparian ecosystems, at least seasonally, throughout their range. The attraction of elk, moose (*Alces alces*), deer (*Odocoileus* spp.), and other ungulates to riparian areas is influenced by the abundance of thermal cover and the microclimates produced by the lush vegetation. Elk are known to use riparian areas for travel lanes and thermal cover, but the relative importance of these ecosystems may vary regionally and seasonally, and overall use by elk is not well understood. Riparian habitats may be especially important for elk during calving (Witmer and deCalesta 1981). In areas of high snowfall, riparian areas may be preferred winter habitat for elk due to reduced snow accumulations and early forage production in the spring (Raedeke, Taber, and Paige 1988). Moose are well known to use riparian habitats in northern forests. During winters of particularly deep snow, moose prefer lowland riparian areas over high-elevation shrub communities (Coady 1982).

Mule deer (*O. hemionus*) are highly variable in their use of riparian ecosystems. In the Pacific Northwest and Great Basin regions, mule deer spend a disproportionate amount of their time in riparian areas due to the availability of cover that helps to minimize energy expenditure. Mule deer frequently use riparian zones along rivers and streams as migration corridors between high-elevation summer range and lower-elevation winter range (Thomas 1979; Thomas, Maser, and Rodiek 1979). Riparian areas also provide important cover for mule deer in the arid Southwest, and are generally considered to be good habitat for black-tailed deer (*O. h. columbiana* and *O. h. sitkensis*) in the coastal range and lowlands of the Pacific Northwest (Raedeke, Taber, and Paige 1988).

The white-tailed deer has been reported to use riparian habitats throughout its range. Compton, Mackie, and Dusek (1988) found that the amount of riparian forest and shrubland cover were the

most important factors influencing the distribution of white-tailed deer along the Yellowstone River in eastern Montana. White-tailed deer populations, including the endangered Columbian subspecies (*O. v. leucurus*), are closely associated with riparian habitats in the Pacific Northwest (Gavin 1984; Raedeke, Taber, and Paige 1988). Winter ranges, usually located along river bottoms and lake-shores, are essential to the welfare of white-tailed deer in the Rocky Mountain region (Peek 1984). Zwank et al. (1979) reported that bottomland hardwoods in the Southeast supported twice as many white-tailed deer per unit area as did upland forests. Mott et al. (1985) found that white-tailed deer used bottomland hardwood forests, especially mature stands, extensively during all seasons.

Other ungulates, such as javelina (*Tayassu tajacu*), will also use riparian habitats. Feral hogs (*Sus scrofa*) often occur in bottomland habitats and can cause considerable damage to the riparian system. Hog activities that impact riparian soils and vegetation include wallowing, rooting, and rubbing (against tree trunks, posts, or other vertical structures), and direct foraging (Dickson, Mayer, and Dickson 2001). Harper, Trame, and Hohmann (1998) stated that hog activity in southeastern wetlands can degrade habitats so severely that they are no longer able to support native ground cover and rare species. Arrington, Toth, and Koebol (1999) reported that although feral hogs can have detrimental effects on native biota and community structures, hog rooting can actually increase plant species richness, at least over the short term. Nevertheless, large populations of feral hogs should be considered potentially damaging to riparian landscapes.

The American black bear (*Ursus americanus*) and grizzly bear (*U. arctos*) are seasonally common in forested riparian areas. In the Pacific Northwest, black bears prefer early successional areas such as brushfields, meadows, and riparian areas (Pelton 1982). In the Northeast, black bears are known to utilize softwood cover types found in larger riparian corridors (DeGraaf and Yamasaki 2000), and bottomland hardwood habitats are important to populations in the Southeast. Grizzly bears are common in riparian habitats in southeastern Alaska, and both black and grizzly bears seasonally occur in riparian areas that support salmon populations. Bears also frequent riparian areas that serve as ungulate winter and calving range, where they feed abundantly on ungulate carrion (Radaeke, Taber, and Paige 1988).

Medium-sized Mammals and Furbearers. Numerous medium-sized mammals are known to occur in riparian systems, but there have been few long-term studies of these species to determine their specific habitat requirements in riparian areas (Ohmart and Anderson 1986). Authors generally agree that a number of medium-sized mammals use riparian areas extensively, but most species also occur in uplands. Aquatic and semi-aquatic species, such as beaver, muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), and river otter (*Lontra canadensis*), are also found in marshlands and lacustrine systems.

In the Pacific Northwest, medium-sized mammals considered to be most dependent on riparian habitats were the beaver, nutria, mink (*Mustela vison*), river otter, and raccoon; a total of 16 medium-sized mammals used forested riparian zones to some extent (Raedeke, Taber, and Paige 1988). Other species present in riparian zones to a lesser extent were the Virginia opossum (*Didelphis virginiana*), snowshoe hare (*Lepus americanus*), eastern cottontail (*Sylvilagus floridanus*), Nuttall's cottontail (*S. nuttallii*), striped skunk (*Mephitis mephitis*), fisher (*Martes pennanti*), and gray fox. The fisher is generally thought to depend on riparian habitats for travel and escape routes (Ohmart and Anderson 1986).

Medium-sized mammals documented to occur in riparian zones in southern California include the beaver, opossum, western gray squirrel (*Sciurus griseus*), porcupine (*Erethizon dorsatum*), coyote (*Canis latrans*), gray fox, red fox (*Vulpes vulpes*), ringtail (*Bassariscus astutus*), raccoon, long-tailed weasel (*Mustela frenata*), striped skunk, spotted skunk (*Spilogale gracilus*), and bobcat. Riparian-dependent species in Arizona and New Mexico include the mink, beaver, muskrat, raccoon, river otter, and Arizona gray squirrel (*S. arizonensis*). In parts of the Southwest, the ringtail and gray fox are more abundant in riparian areas than elsewhere. Although porcupines are normally considered upland forest inhabitants, they have been recently documented in riparian areas (Laurendine, Morton, and Chesemore 1996), especially where upland areas have been extensively disturbed. Medium-sized mammals that occur commonly in riparian habitats of southern Texas include the opossum, armadillo (*Dasypus novemcinctus*), raccoon, bobcat, coyote, and eastern cottontail.

Medium-sized mammals with a strong preference for riparian habitats in the eastern United States include the beaver, muskrat, raccoon, river otter, fisher, ermine (*Mustela erminea*), mink, and long-tailed weasel. The eastern cottontail, New England cottontail (*Sylvilagus transitionalis*), and red fox may also be found in riparian areas in the Northeast (DeGraaf and Yamasaki 2000). Species commonly occurring in riparian bottomlands of the Southeast are beaver, muskrat, nutria, raccoon, opossum, bobcat, mink, long-tailed weasel, and swamp rabbit (*S. aquaticus*) (Figure 3). Beavers and river otters are dependent on aquatic resources associated with riparian areas. Minks concentrate their activities near water, whereas raccoons wander over larger areas that might include permanent water and uplands. The muskrat and nutria also occur in other wetland systems (e.g., marshes, lakes and ponds, coastal areas) but may be common in riparian areas as well. Swamp rabbits, bobcats, and gray foxes concentrate their activities on bottomland sites during low-water periods (Fredrickson 1978). Although the swamp rabbit historically was the dominant rabbit of bottomland regions in the lower Mississippi Valley region, both it and the eastern cottontail are now found in almost equal numbers in bottomlands because of the conversion of many bottomland hardwood areas to agriculture (Glasgow and Noble 1971). Both gray and fox squirrels inhabit upland and lowland hardwoods, but the gray squirrel is more closely tied to bottomland hardwood corridors in the Southeast (Warren and Hurst 1980).

Figure 3. The swamp rabbit (*Sylvilagus aquaticus*) is a characteristic species in bottomland habitats of the Lower Mississippi Valley

Beavers often play a significant role in the development and maintenance of riparian habitat and stream function (Raedeke, Taber, and Paige 1988) (Figure 4). Beaver dams form small lakes within stream systems that can modify conditions in the surrounding forest by creating changes in local hydrologic patterns and nutrient cycling. Created ponds help regulate streamflow during high water and maintain low-water flows, thus enhancing vegetative productivity. Also, habitat alterations resulting from the dam-building and foraging activities of beavers can benefit numerous semi-aquatic and terrestrial species (DeGraaf and Yamasaki 2000). Beavers are considered critical to the occurrence and distribution of lowland hardwood wetlands because of their ability to change water conditions within their home ranges (Fredrickson 1978). Beaver activity has been reported to benefit riparian and aquatic systems by creating and expanding wetlands, elevating water tables, enhancing forage and cover, improving watershed stability, reducing high flows and downstream flooding, providing more constant flows through water storage, retaining sediment and organic matter, improving bank stabilization, reducing the channel gradient, increasing aquatic invertebrate production, and increasing total aquatic productivity (Naiman, Melillo, and Hobbie 1986; Parker 1986; Olson and Hubert 1994). However, when overabundant, beaver activity can result in adverse impacts to forested systems by increased flooding and reduction of shoreline vegetation in riparian areas (Moore 1967).

Figure 4. Beaver (*Castor Canadensis*) activity plays a significant role in the development and maintenance of riparian habitat and stream function

Small mammals. Riparian ecosystems provide important habitat for numerous small mammals, but specific requirements are highly variable. For example, burrowing mammals are dependent on soil texture, structure, and moisture, whereas arboreal species such as tree squirrels require suitable woody vegetation (e.g., hardwood tree species, vertical layering, and mast availability), and jumping mice (*Zapus* spp.) are affected by grass height and stem densities (Ohmart and Anderson 1986). Although several studies have reported high species diversity, abundance, and reproductive activity of small mammals in riparian areas, the importance of riparian habitat to small-mammal communities is not well-documented (Ellison and van Ripper 1998). Hanley and Barnard (1999) stated small mammals may be year-round residents of riparian forests and may be strongly influenced by periodic flooding and the unique characteristics of these forests. Small mammal communities in alluvial floodplains often are dominated by a few species that sometimes vary among hydrologic zones (Wigley and Lancia 1998). A variety of shrews, moles, voles (*Microtus* spp.), jumping mice, and *Peromyscus* spp. are regionally characteristic of riparian ecosystems. Regional examples of small mammals reported to occur in riparian habitats are provided in Appendix A, Tables A1-A4.

Bats are often closely associated with riparian habitats. Almost all bats require open water for drinking, and in some cases aquatic areas associated with riparian zones represent the only available water in a local area. Bats also use riparian areas for roosting, as foraging habitat, and as movement corridors. The importance of riparian areas as bat foraging habitat has been well-documented (Furlonger, Dewar, and Fenton 1987; Grindal 1995; Seidman and Zabel 2001). Cross (1988) suggested that the use of a given forest riparian habitat for drinking or feeding by bats was most likely determined by the proximity of suitable roosting sites. However, some species travel long distances from their roosts to drinking and foraging sites. Riparian areas have been identified as especially important feeding areas for bats in arid regions (Bell 1980), and they were found to be the most important foraging sites for bats in southeastern Alaska temperate rain forests (Parker, Cook, and Lewis 1996).

Riparian ecosystems provide important habitat for several endangered bat species and species of concern in the East (Figure 5). Maternity colonies of Indiana bats (*Myotis sodalis*) are most often located in floodplain deciduous forests or upland hardwood stands adjacent to riparian or floodplain forests (Garner and Gardner 1992, U.S. Fish and Wildlife Service 1999). Gray bats (*M. grisescens*) forage primarily over water along rivers or lake shores where flying insects are abundant, and summer colonies inhabit areas where streams, lakes, and reservoirs are reasonably close to roosting sites and maternal caves (LaVal, LaVal, and Caire 1977; Brady et al. 1982). Because of the need for surface water and roost sites located near foraging and watering areas, bats may be better indicators of riparian habitat quality than most other mammals. Appendix A, Tables A5-A8 show regional variation in bat species associated with riparian habitats.

Figure 5. The Southeastern bat (*Myotis austroriparius*) and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) are species of concern that are highly dependent on riparian areas in the Southeast

HABITAT DISTURBANCE: The impacts of riparian habitat modification and disturbance are not as clear for most mammals as they are for birds, reptiles, and amphibians. As with other wildlife, activities that potentially affect mammal populations include silviculture, grazing, agriculture, channelization, dam construction, urbanization, road construction, mining, invasion of exotic species (plants and animals), and groundwater withdrawals. However, specific impacts have not been determined for most mammals, especially nongame species.

Timber management practices alter habitat for mammals by affecting the availability of hard and soft mast, browse, invertebrates, tree cavities, ground-level vegetation, vertical structure, and downed woody material (Forsythe and Roelle 1990). Decreasing the availability of these components over large, contiguous areas will decrease habitat suitability for such species as the gray squirrel, southern flying squirrel (*Glaucomys volans*), and raccoon. However, populations of some small mammals may increase after logging due to the increase in ground-level vegetation, increased ground-level cover from logging slash, and greater food production for some species (McComb and Noble 1980; Wesley, Perkins, and Sullivan 1981). Healy and Brooks (1988) reported that intermediate thinning and clearcutting treatments had minimal or ephemeral effects on the numbers and composition of small mammals in hardwood forests of West Virginia and Massachusetts. However, clearcutting and extensive logging of mature forest stands can be detrimental to many species, especially bats. For example, Hayes and Adam (1996) found that bat activity averaged 4.1 to 7.7 times higher in wooded riparian areas than in adjacent logged areas in western Oregon.

There is considerable disagreement regarding the impacts of grazing on mammal populations. Ohmart and Anderson (1986) stated that small mammals are adversely affected by livestock grazing in riparian communities, but some investigators have reported increased rodent species richness under moderate or heavy grazing pressures (Moulton 1978). Samson, Knopf, and Hass (1988) found little effect of winter grazing on small mammal numbers or habitat use in Colorado cottonwood floodplains. However, small mammal species richness and diversity were higher in Nevada riparian exclosures than in adjacent grazed riparian areas (Medin and Clary 1988). Ohmart and Anderson (1986) suggested that small mammal species that increase with grazing are usually generalists with broad habitat requirements. Conversely, habitat specialists, including many microtine rodents, usually decrease when grazing pressure is high.

Channelization is generally reported to be detrimental to larger mammals because of the removal of streamside vegetation and resultant deterioration of habitat quality. Fredrickson (1978) reported that following channelization, riparian habitat is nonexistent along new channels, and species such as river otter, mink, beaver, and muskrat disappear. Species such as gray squirrels and raccoons are especially affected by hydrologic changes in floodplain forests (Glasgow and Noble 1971). However, some studies have found that small mammal species diversity was higher in channelized habitats than unchannelized areas due to increased groundcover, especially grasses (Geier and Best 1980). Although several small mammal species may benefit from reduced flooding, most of these are species that are widespread across the landscape. For example, cotton rat (*Sigmodon hispidus*) and deer mouse (*Peromyscus maniculatus*) habitat might be improved by channelization, but increases in populations of these species should not be interpreted as indicating habitat improvement. Possardt and Dodge (1978) found that shrews and jumping mice declined along channelized streams in Vermont, whereas white-footed mice (*P. leucopus*) and meadow voles (*Microtus pennsylvanicus*) were not affected.

MANAGEMENT: Few comprehensive studies have been conducted on management needs for entire mammalian communities associated with riparian ecosystems. Issues that need to be addressed include the following (Cross 1988):

- Effects of various widths, lengths, and vegetative composition on resident and transient wildlife species.
- Inclusion of adjacent upland habitat as part of riparian management areas.
- Optimal length and/or width of riparian areas for most species.
- Regional variation in optimal or minimal dimensions.
- Variation in dimensions among species.

Raedeke, Taber, and Paige (1988) noted the following issues in managing large mammals in forested riparian systems:

- Impact of forest management outside of riparian areas.
- Availability and abundance of food items in riparian areas.
- Importance of riparian areas as travel corridors.
- Importance of retaining closed-canopy forest patches in riparian areas.
- Configuration of riparian buffers.
- Use of large patches versus long strips along streams.
- Impact of partial timber removal.
- Comparison of the impacts of timber harvest with that of natural disturbance.

Retaining riparian areas along streams may provide essential habitat and/or travel corridors among fragmented forests for many wildlife species (Dickson 1989). This is especially important in light of the overall reduction of bottomland hardwoods throughout the eastern states and the conversion of mature pine-hardwood forests to even-aged pine plantations. Dickson and Williamson (1988) recommended that streamside management zones be established for the conservation and management of small mammals and other wildlife in the Southeast. These areas improve habitat diversity and edge, offer suitable habitat for wildlife species associated with mature timber stands, serve as travel corridors, and may permit genetic interchange between otherwise isolated populations.

The recruitment and retention of snags and maintenance of structural complexity in forest patches in upland as well as riparian areas are important for bat management (Campbell, Hallett, and O'Connell 1996). Large mature trees are most often selected as roost sites by bats (Cross 1988, Betts 1998, Rabe et al. 1998). Krusic et al. (1996) recommended a combination of over-mature hardwoods, clearcuts, and group cuts to provide feeding and roosting resources for forest bats during

the summer. However, several studies have indicated that bats are not common in large openings, including clearcuts (Brigham and Barclay 1996). Seidman and Zabal (2001) found that stream sites with channel widths more than 1.8 m (6.0 ft) had significantly more bat activity than upland sites or stream sites with channel widths less than 1.2 m (4.0 ft) in northwestern California; however, all stream sites sampled were used by bats.

Riparian areas are so variable regionally, and even locally, that generalized animal-to-habitat relationships are difficult to develop (Thomas, Maser, and Rodiek 1979). Thus, management plans must include a specific set of relationships for each particular case. In many areas, riparian zones represent the area of maximum potential conflict among users of timber, grazing, recreation, water, and wildlife resources (Thomas, Maser, and Rodiek 1979), which further indicates the importance of careful and well-coordinated management strategies. The following basic recommendations apply to managing riparian habitats for a diversity of mammals (after Thomas, Maser, and Rodiek (1979); DeGraaf et al. (1992); DeGraaf and Yamasaki (2000); and others):

- Maximize size of the riparian zone; consider extending the widths of managed riparian zones well beyond widths recommended for streambank protection and maintaining water quality.
- Provide corridor protection from grazing or human disturbance through fencing or other means, when necessary.
- Connect habitat patches by restoring and protecting disturbed sections of habitat.
- Limit new roads in riparian areas and consider reducing the traffic on existing roads, especially during reproductive periods (e.g., calving, presence of bat maternity colonies).
- Increase availability of water within the riparian corridor through wetland restoration activities.
- Manage for a variety of vegetative conditions, forest cover types, sizes, and size classes.
- Consider site, slope, aspect, soil types, and seasonal limitations when developing stand-level timber management prescriptions for riparian areas.
- Minimize harvest in riparian areas, and maintain a "no-cut" buffer zone immediately adjacent to streams.
- Select uneven-aged management prescriptions, and manage for longer rotation periods.
- Avoid long, linear clearcuts adjacent to riparian areas.
- Avoid cutting "undesirable" trees (also referred to as "wildlife" or "wolf" trees).
- Manage for high densities of cavity trees and snags, especially large-diameter trees; also manage for cavity trees in adjacent uplands.

- Increase dead and downed woody debris, and limit fuelwood harvest.
- Encourage the development of distinct shrub layers, thickets, and grass/sedge and herbaceous ground cover.
- Limit grazing activity at the water's edge and reduce the intensity of use on streamside forage.

SUMMARY: Mammals are important to riparian ecosystems, but their occurrence and dependence on riparian areas is highly variable. Many mammals use riparian habitats for food, water, and cover, especially in arid and semi-arid regions, but few species are restricted to riparian areas. Riparian habitat features important to mammals include woody and herbaceous strata, diversity of food and cover plants, structural diversity, friable soil, available surface water, invertebrates and other prey items, and thermal cover. Cavity trees, dead and downed woody debris, wetland edges, young and mature hardwood stands, and coniferous habitats are needed by mammals inhabiting riparian areas in eastern forests. Features important to mammals in bottomland hardwood forests include hard and soft mast, browse, invertebrates, ground-level vegetation, arboreal cavities, vertical structure, and downed woody debris.

Mammalian communities that inhabit riparian ecosystems are highly variable. Many large mammals depend on riparian habitats, at least seasonally, throughout their range. The attraction of elk, moose, deer, and other ungulates to riparian areas is influenced by the abundance of thermal cover and the microclimates produced by the lush vegetation. Bears are also seasonally common in forested riparian areas. Numerous medium-sized mammals occur in riparian systems, but few species are obligate riparian species. Riparian ecosystems provide important habitat for numerous small mammals, but specific requirements are highly variable. Many bat species are closely associated with riparian habitats. Because of their need for surface water and roost sites located near foraging and watering areas, bats may be better indicators of riparian habitat quality than most other mammals.

As noted by Fischer and Hamilton (2001), Corps of Engineers projects represent significant resources that likely play an important role in the health and vigor of wildlife populations within and beyond project boundaries. Corps projects throughout the United States provide important habitat for numerous species of mammals, and the location of many projects along navigable streams makes them especially attractive to riparian-dependent species. However, few studies have been conducted to determine the role that the Corps plays or what management prescriptions are needed on Corps lands to improve habitat for these species (Hamilton and Fischer 2001). Many projects support game management programs and collect seasonal harvest data on selected species (often through agreements with state wildlife agencies), but little information is available on the use of Corps lands by nongame species. Systematic surveys are needed to document the occurrence of mammal species on Corps lands and determine the importance of existing habitat types, especially wetlands and riparian areas, to various taxa. Management prescriptions should then be developed that benefit both game and nongame species.

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APPENDIX A

Table A1
Small Mammals (less bats) That Depend on Riparian Zones for Providing Optimal Habitat in Coniferous Forests of Washington, Oregon, and Northern California (Cross 1988)

Pacific water shrew (*Sorex bendirii*)	Northern flying squirrel (*Glaucomys sabrinus*)
Dusky shrew (*Sorex monticolus*)	Deer mouse (*Peromyscus maniculatus*)
Pacific shrew (*Sorex pacificus*)	White-footed vole (*Arborimus albipes*)
Water shrew (*Sorex palustris*)	Creeping vole (*Microtus oregonii*)
Shrew mole (*Neurotrichus gibbsii*)	Water vole (*Microtus richardsoni*)
Broad-footed mole (*Scapanus latimanus*)	Western jumping mouse (*Zapus princeps*)
Mountain beaver (*Aplodontia rufa*)	Pacific jumping mouse (*Zapus trinotatus*)

Table A2
Small Mammals (less bats) Documented in Riparian Habitats in Central and South-Central New Mexico and Adjacent West Texas (Jorgensen, Demarais, and Neff 1995; Ellis, Crawford, and Molles 1997; C. O. Martin, unpublished data)

Desert shrew (*Notiosorex crawfordi*)	Northern grasshopper mouse (*Onychomys leucogaster*)
White-footed mouse (*Peromyscus leucopus*)	Botta's pocket gopher (*Thomomys bottae*)
Deer mouse (*Peromyscus maniculatus*)	Desert pocket mouse (*Chaetodipus penicillatus*)
Cactus mouse (*Peromyscus eremicus*)	Rock pocket mouse (*Chaetodipus intermedius*)
Brush mouse (*Peromyscus boylii*)	Silky pocket mouse (*Perognathus flavus*)
Western harvest mouse (*Reithrodontomys megalotis*)	Plains pocket mouse (*Perognathus flavescens*)
Hispid cotton rat (*Sigmodon hispidus*)	Merriam's kangaroo rat (*Dipodomys merriami*)
White-throated woodrat (*Neotoma albigula*)	Ord's kangaroo rat (*Dipodomys ordii*)
House mouse (*Mus musculus*)	

Table A3
Small Mammals (less bats) That Occur in Riparian Habitats in the Northeastern United States (DeGraaf and Yamasaki 2000)

Arctic shrew (*Sorex arcticus*)[1]	Deer mouse (*Peromyscus maniculatus*)
Water shrew (*Sorex palustris*)[1]	White-footed mouse (*Peromyscus leucopus*)
Southeastern shrew (*Sorex longirostris*)[1]	Southern red-backed vole (*Clethrionomys gapperi*)
Smoky shrew (*Sorex fumeus*)	Meadow vole (*Microtus pennsylvanicus*)
Short-tailed shrew (*Blarina brevicauda*)[1]	Southern bog lemming (*Synaptomys cooperi*)
Star-nosed mole (*Condylura cristata*)[1]	

[1] Species with a strong preference for riparian habitats.

Table A4
Small Mammals (less bats) Found in Bottomland Hardwoods in the Lower Mississippi Valley (Klimas, Martin, and Teaford 1981)

Southeastern shrew (*Sorex longirostris*)[1]	Short-tailed shrew (*Blarina brevicauda*)
White-footed mouse (*Peromyscus leucopus*)[1]	Eastern mole (*Scalopus aquaticus*)
Cotton mouse (*Peromyscus gossypinus*)[1]	Deer mouse (*Peromyscus maniculatus*)
Golden mouse (*Ochrotomys nuttali*)[1]	Eastern chipmunk (*Tamias striatus*)
Eastern woodrat (*Neotoma floridana*)[1]	Southern flying squirrel (*Glaucomys volans*)
Marsh rice rat (*Oryzomys palustris*)	Armadillo (*Dasypus novemcinctus*)

[1] Species with an apparent preference for wooded bottomlands.

Table A5
Bat Species Documented Along the Rio Grande, New Mexico (various sources)[1]

Pallid bat (*Antrozous pallidus*)	Little brown bat (*Myotis lucifugus*)
Big brown bat (*Eptesicus fuscus*)	Long-legged bat (*Myotis volans*)
Spotted bat (*Euderma maculatum*)	Yuma bat (*Myotis yumanensis*)
Silver-haired bat (*Lasionycteris noctivagans*)	Western pipistrelle bat (*Pipistrellus hesperus*)
Eastern red bat (*Lasiurus borealis*)	Townsend's big-eared bat (*Corynorhinus townsendii*)
Hoary bat (*Lasiurus cinereus*)	Big free-tailed bat (*Nyctinomops macrotis*)
California bat (*Myotis californicus*)	Brazilian free-tailed bat (*Tadarida brasiliensis*)
Western small-footed bat (*Myotis ciliolabrum*)	

[1] Bat common and scientific names follow Harvey, Altenbach, and Best (1999).

Table A6
Bats That Occur in Coniferous Forest and Associated Riparian Habitat in the Western United States (Cross 1988)

Pallid bat (*Antrozous pallidus*)	Western long-eared bat (*Myotis evotis*)
Big brown bat (*Eptesicus fuscus*)	Keen's bat (*Myotis keenii*)
Silver-haired bat (*Lasionycteris noctivagans*)	Little brown bat (*Myotis lucifugus*)
Western red bat (*Lasiurus blossevillii*)	Fringed bat (*Myotis thysanodes*)
Hoary bat (*Lasiurus cinereus*)	Long-legged bat (*Myotis volans*)
California bat (*Myotis californicus*)	Yuma bat (*Myotis yumanensis*)
Western small-footed bat (*Myotis ciliolabrum*)	Townsend's big-eared bat (*Corynorhinus townsendii*)

Table A7
Bat Species with a Strong Preference for Riparian Habitats in the Northeast (DeGraaf and Yamasaki 2000)

Big brown bat (*Eptesicus fuscus*)	Little brown bat (*Myotis lucifugus*)
Silver-haired bat (*Lasionycteris noctivagans*)	Northern long-eared bat (*Myotis septentrionalis*)
Eastern red bat (*Lasiurus borealis*)	Indiana bat (*Myotis sodalis*)
Hoary bat (*Lasiurus cinerus*)	Eastern pipistrelle (*Pipistrellus subflavus*)

Table A8
Bat Species Documented in Bottomland Hardwood Habitat in Eastern Arkansas (Cochran et al. 1999) and West-Central Mississippi (L. Wilf and J. D. Wilhide, unpublished Data)

Big brown bat (*Eptesicus fuscus*)	Northern long-eared bat (*Myotis septentrionalis*)
Eastern red bat (*Lasiurus borealis*)	Evening bat (*Nycticeius humeralis*)
Seminole bat (*Lasiurus seminolus*)	Eastern pipistrelle (*Pipistrellus subflavus*)
Southeastern bat (*Myotis austroriparius*)	Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)
Little brown bat (*Myotis lucifugus*)	